ATTACHMENT J.4.47

LETTER REPORT ON RESIDUE RETRIEVAL METHODS FOR SILOS 1-3

MARCH 1996 REV. 0

Letter Report on Residue Retrieval Methods for Silos 1-3

Operable Unit 4
Project Order 161
Task 120

March 1996
Revision 0

Environmental Remedial Action Project
Fernald Environmental Management Project
Fernald, Ohio
FERMCO Subcontract No. 2-21487

PARSONS

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Letter Report on
Residue Retrieval Methods
for Silos 1-3

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LIST OF ACRONYMS AND ABBREVIATIONS

D&D	Decontamination and Decommissioning
DCP	Design Criteria Package
DOE	United States Department of Energy
FEMP	Fernald Environmental Management Project
fps	feet per second
FRVP	Fernald Residues Vitrification Plant
gpm	gallons per minute
hr	hour
lb	pound
OU	Operable Unit
PO	Project Order
VITPP	Vitrification Pilot Plant

SECTION 1

INTRODUCTION AND OBJECTIVE

The Fernald Environmental Management Project (FEMP) established operations in 1951 under orders of the Atomic Energy Commission and produced uranium and other metals for use at other United States Department of Energy (DOE) facilities. Production at the FEMP has ceased and the environmental remediation of the entire site is ongoing. To aid in the remediation effort the FEMP is separated into five Operable Units (OUs). OU-4 is on the west-central boundary of the FEMP and includes four silos: Silos 1 and 2 (also known as the K-65 Silos), Silo 3, and Silo 4. Silos 1 and 2 contain radium-bearing residues from pitchblende ore processes. This material is subsequently referred to as K-65 waste. Silo 3 contains dry uranium oxide and other metal oxides. Silo 4 is empty and has never been used. For a detailed description of the contents of Silos 1, 2, and 3, refer to the *Remedial Investigation Report for Operable Unit 4* (DOE 1993).

As described by the *Final Record of Decision for Remedial Actions at Operable Unit 4* (DOE 1994), the treatment technology selected for the processing of the silo contents is vitrification. To be treated (vitrified), the silo residues must be removed from the silos and transported to the treatment facility. Residue retrieval systems will be designed and constructed for this purpose. The current design approach includes the construction of superstructures over Silos 1, 2, and 3 to be used as support platforms for the residue retrieval systems. As documented in the *Functional Requirements Document for the Fernald Residues Vitrification Plant* (DOE 1995a) and the *Design Criteria Package for the Fernald Residues Vitrification Plant* (DOE 1995b), Silos 1 and 2 residues shall be slurried and pumped (hydraulically transferred) to the vitrification facility while, due to the powdery nature of the Silo 3 metal oxide residues, a pneumatic process shall be used to retrieve and transport its contents to the vitrification facility (DOE 1994).

This study is concerned with examining these methods of retrieval as the primary means of residue retrieval. The initial or primary retrieval is referred to, in this study, as bulk retrieval. This is in contrast to the retrieval means employed to remove the residue remaining in the silos after bulk retrieval operations are completed. This residue is referred to as the residue "heel." Other (secondary) means of retrieval will be employed for this material and are referred to generically in this study as "heel retrieval operations."

The objective of this letter report is to qualitatively evaluate the waste retrieval methods previously studied and identified in the *Operable Unit 4 Remedial Action Conceptual Design Report* (PARSONS 1992b), the Project Order 92 (PO-92) *Silo 4 Waste Removal and Transporting System Project*, and the PO-137 *Residue Removal/Treatment Design*, along with other waste retrieval methods used in industry and at other DOE facilities. This report documents this evaluation and includes a recor .mended waste retrieval method for each of the silos.

The results of this letter report provide the basis for development of the conceptual design for the Silos 1, 2, and 3 residue retrieval systems. This in turn will be applied to produce a pre-final design package for the silo superstructures, and future detailed design and installation of the residue retrieval systems themselves. This letter report is prepared to satisfy the requirements of the PO-161 Statement of Work as described in Subsection 2.3.1 of the *Project Order Plan for Project Order 161* (PARSONS 1995a).

SECTION 2

SUMMARY

This section provides, in tabular form, a brief description of each of the evaluated alternatives and ratings for each of the criteria evaluated. The summary tables provide a rating for each scenario for each of five evaluation criteria. The ratings for each scenario are totaled to provide an overall indication of the attractiveness of that scenario in comparison to the others. Tables 2-1 and 2-2 present this information. A discussion of the evaluation criteria is presented in Section 3. The complete description of each alternative and discussion of the criteria ratings for the K-65 and Silo 3 residues are located in Sections 4 and 5, respectively.

2.1 K-65 Residue

The recommended alternative is Scenario 7 based on the overall criteria ratings as listed in Table 2-1. This scenario utilizes a submersible pump with integral spray ring and submerged jet nozzle deployed from the silo superstructure through the enlarged center manway. The pump is augmented by remotely operated unsubmerged jets mounted in two of the silo's outer manways. The higher capital cost for the equipment in this scenario is more than offset by the greater operability, and usefulness in Decontamination and Decommissioning (D&D) operations. (See Figure 4-8 for a schematic of Scenario 7.)

2.2 Silo 3 Residues

The recommended scenario is Scenario No. 1 based on the overall criteria ratings as listed in Table 2-2. In this scenario access to the silo residues is provided through two new penetrations in the silo wall at grade. Mechanically assisted pneumatic retrieval devices and a segmented vacuum tube are inserted through these openings to perform bulk retrieval. This scenario does not require the construction of a silo superstructure. The Houdini vehicle can be inserted through an enlarged grade penetration for heel removal. (See Figure 5-3 for a schematic of Scenario 1.)

Table 2-1 - Summary of K-65 Residue Retrieval Scenarios

Scenario	Description	Effectiveness and Operability	Reliability	Safety, Containment, and Exposure	Cost	Usefulness for D&D	Overall Score
1	Submersible hydraulic mining pump with submerged jet deployed through enlarged center manway.	2	4	4	5	2	17
2	Large submersible mixer and additional submersible pump deployed through enlarged center manway.	3	4	4	3	2	16
3	Submersible hydraulic mining pump with unsubmerged jet deployed through enlarged center manway.	3	4	4	4	3	18
4	Submerged jet pump with integral jet nozzle deployed through enlarged center manway.,	3	4	2	3	3	15
5	Vertical centrifugal pump with integral jet nozzle deployed through enlarged center manway.	3	3	4	2	5	17
6	Four small submersible pumps deployed through four existing outer manways; unsubmerged jet deployed through existing center manway.	4	4	3	3	4	18
7	Submersible pump with submerged jet deployed through enlarged center manway. Two unsubmerged jets mounted in outer manways.	5	4	4	2	5	20

Table 2-2 - Summary of Silo 3 Residue Retrieval Scenarios

Scenario	Description	Effectiveness and Operability	Reliability	Safety, Containment, and Exposure	Cost	Usefulness for D&D	Overall Score
1	Pneumatic retrieval equipment is inserted through two new wall penetrations at the base of the silo	3	3	5	4	3	18
2	Small vacuum tubes inserted through existing silo decant ports	2	2	3	4	3	14
3	Straight vacuum tubes inserted through five existing manways	4	3	2	2	4	[illegible]
4	Remote-controlled articulated arms deploy vacuum tubes through three existing manways	5	3	2	3	4	17
5	Houdini robot deploys vacuum tube through enlarged manway	5	2	4	3	3	17

SECTION 3

DISCUSSION OF CRITERIA

All scenarios were evaluated against the following criteria:

1) Effectiveness and operability
2) Reliability
3) Safety, containment, and exposure
4) Cost
5) Usefulness for D&D operations

A description of each criterion is provided below. A numerical rating (integer 1 through 5) was assigned to each scenario evaluated under each criteria. The rating system is qualitative in nature; the significance of each rating is listed in Table 3-1. It should be emphasized that, while quantitative criteria were applied where they were readily available, ratings based on general design approaches are inherently somewhat judgmental as they are based in part on the experiences and opinions of the design engineers. A rating system was selected over a ranking of scenarios to allow the assignment of equal ratings to scenarios which were relatively equal for a given criterion.

Table 3-1 - Criteria Rating Significance

Rating	Significance
1	Significant negative impact when compared to the other scenarios
2	Minor negative impact when compared to the other scenarios
3	Equivalent when compared to the other scenarios
4	Minor positive impact when compared to the other scenarios
5	Significant positive impact when compared to the other scenarios

3.1 Effectiveness and Operability

Overall assessment of the design's ability to remove residue from the silo effectively. This criteria includes the ability to remove a major portion of the residue leaving a small heel, the ability to remove residue of varying consistency, and the degree to which operations will be disrupted by the presence of discrete objects or the ability of the design to work around them.

3.2 Reliability

Reliability considers the overall assessment of the reliability of the equipment utili ed by the scenario. Maturity of selected technology, degree of complexity of the equipment, and demons rated successful use in similar applications are all considered by this assessment.

3.3 Safety, Containment, and Exposure

These criteria evaluate the overall safety of the operation of the equipment selected by the scenario as well as installation, maintenance, and any required transfer of components which may affect containment concerns. These criteria also evaluate the frequency and duration of activities requiring personnel presence on the silo superstructure and within radiation fields.

3.4 Cost

This criterion provides a qualitative assessment of the relative cost of this scenario in relation to the others. Costs which are included are direct equipment cost for primary retrieval equipment including increased costs for superstructure, number of silo access points required, required enlargement or significant modification of silo access points, and the need for elaborate transfer of equipment or other labor intensive evolutions.

3.5 Usefulness for D&D Operations

This criterion provides a qualitative assessment of the degree to which the superstructure, equipment room, and equipment used for bulk retrieval could also be used for heel removal and D&D operations following bulk retrieval.

3.6 Overall Rating

This rating is a sum of the ratings assigned for the other five criteria where all five criteria are given equal weight. This total provides an indication of the overall desirability of the design scenario.

SECTION 4

HYDRAULIC RETRIEVAL OF K-65 RESIDUES

The hydraulic residue transfer system will be sized to support a Fernald Residues Vitrification Plant (FRVP) glass production rate of 24 tons per day as given in the Design Criteria Package (DCP) (DOE 1995b). The system will operate on a daily basis for one shift per day (assume 4 hours actual transfer time).

The retrieval system will be able to supply slurry from both Silos 1 and 2 to support formulations that may require equal parts from Silos 1 and 2, or 100 percent demand from either Silo 1 or 2.

Based on a formulation that uses the maximum K-65 material per pound of glass (only K-65 material and additives - no Silo 3 material) the transfer system must supply 30,720 pounds per day of "dry" K-65 solids. At a 15 percent solids loading, the slurry transfer rate would be 92 gpm. The existing Marconaflo pump has adequate capacity (140 gpm) for this service. The Marconaflo value is carried forward in the evaluated scenarios as a conservative point of comparison. It is assumed by this study, that the FRVP will accommodate the flow rate of 140 gpm. Table 4-1 presents the average results of the analysis of K-65 residue. Figure 4-1 shows the distribution of particle diameters for the K-65 residues.

4.1 Discrete Object and Heel Removal

All scenarios evaluated will consider the use of a reconfigurable in-tank mobile robot (Houdini) for discrete object and heel removal. Houdini is presently under development by RedZone Robotics, Inc., for the DOE, Morgantown Energy Technology Center (RedZone 1995). Houdini will be lowered into the silo by its tether through the enlarged center manway.

During bulk retrieval operations, water will be added to the residues in Silos 1 and 2 to generate a pumpable slurry. During this time Houdini will be of limited use in discrete object management due to its likely inability to operate on the slurry surface. Houdini, however, may be lowered into the silo to retrieve or manipulate objects in the immediate vicinity of the hydraulic pump (where they will be of most concern) using its manipulator arm while hanging in an overhead position.

Following bulk retrieval, when sufficient material has been removed from the silo, Houdini will be able to operate more freely within the silo to perform heel removal and additional discrete object removal. Objects will be secured by Houdini's hydraulic powered manipulator arm and transported to the center of the silo where the objects can be retrieved. Additionally, Houdini can use its attached plow blade and a number of other manipulator-held tools to move heel material and perform local sluicing operations.

Table 4-1 - Silos 1 and 2 Sample Analysis Results

Sieve Analysis (IT 1992)		
Sieve No.	**Diameter (mm)**	**Percent Passing by Weight**
3.0 inches	75.000	100.0
1.5 inches	37.500	100.0
0.75 inches	19.000	100.0
0.375 inches	9.500	100.0
No. 4 (4,760 micron)	4.750	99.4
No. 10 (2,000 micron)	2.000	98.1
No. 20 (841 micron)	0.850	93.8
No. 40 (420 micron)	0.425	87.5
No. 60 (250 micron)	0.250	79.9
No. 140 (105 micron)	0.106	56.8
No. 200 (74 micron)	0.075	48.2
Hydrometer Analysis		
Sieve No.	**Diameter (mm)**	**Percent Passing by Weight**
36 micron	0.0358	41.2
26 micron	0.0263	36.0
17 micron	0.0170	32.6
10 micron	0.0100	29.2
6 micron	0.0059	24.6
5 micron	0.0050	22.3
4 micron	0.0038	19.4
3 micron	0.0027	15.4
1 micron	0.0011	8.6

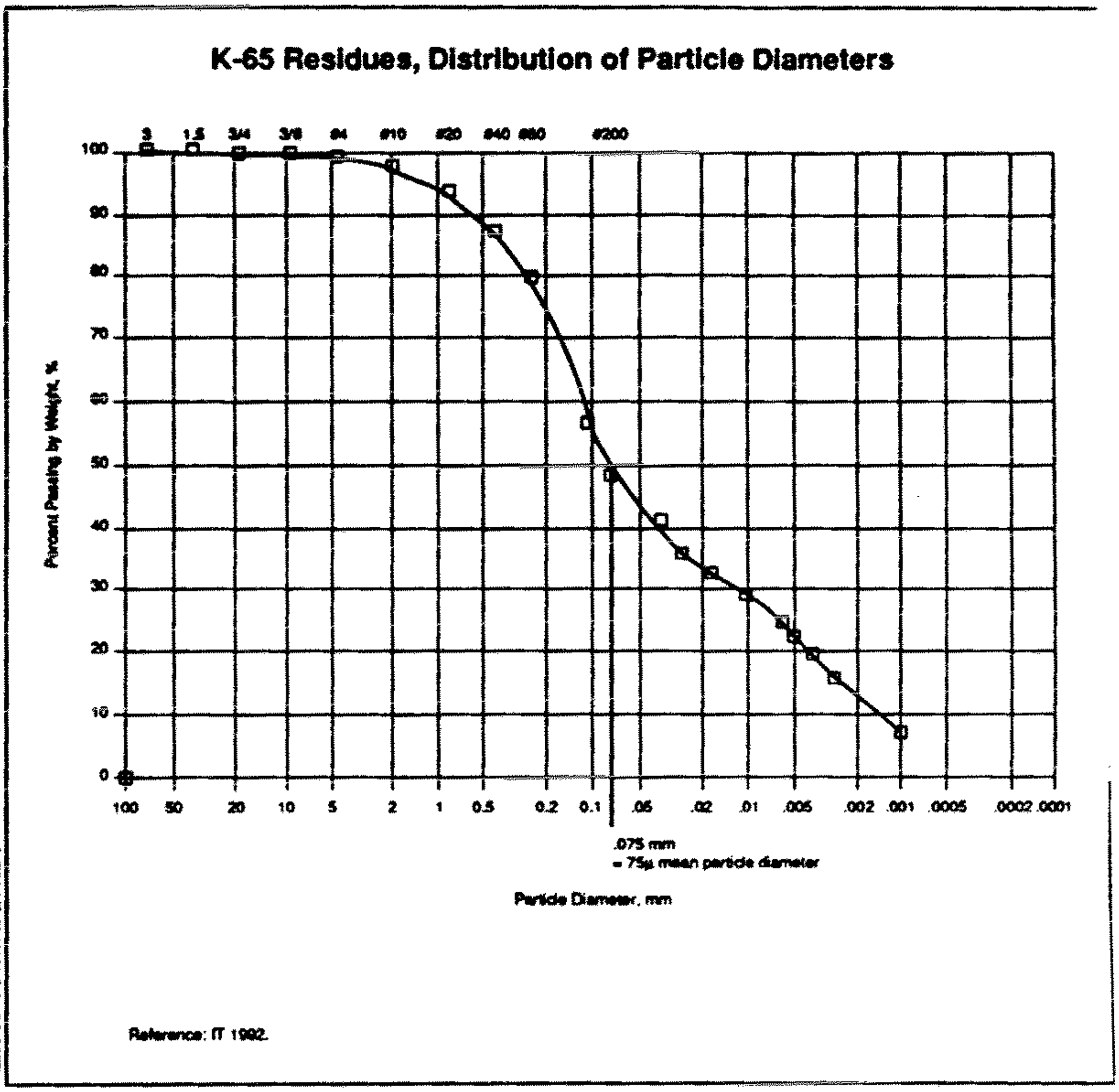

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Figure 4-1 - K-65 Residues, Distribution of Particle Diameters

4.2 Hydraulic Retrieval Alternatives

As discussed in the introduction, for Silos 1 and 2, this letter report is limited to evaluating various configurations of hydraulic retrieval. Hydraulic retrieval is composed of two unique and separate operations. The first is the mobilization of the K-65 residue, in which the residue particles are suspended in a liquid slurry. The second is the transportation of the slurry to the pump for transfer out of the silo. Using past data from hydraulic mining operations (Peele 1941), it appears that an unsubmerged single-point sluice nozzle operated at 135 gpm at 200 feet per second (fps) nozzle exit velocity would provide the required energy with a large safety factor to meet the design basis retrieval rate for the K-65 Silos.

It was previously determined (PARSONS 1992b) that it would not be practicable to access the K-65 residues through the walls of Silos 1 and 2 due to the presence of the surrounding berms, and the complications and silo structural concerns involved in berm excavation to provide access to the silo walls. For this reason, all of the scenarios evaluated for Silos 1 and 2 access the K-65 residues through the silo domes. Alternatives that adversely impact the structural integrity of the silo domes were also excluded from consideration in this report. One such alternative was to cut five large openings in the silo dome for deployment of the existing Marconaflo pump (procured under the Vitrification Pilot Plant [VITPP] Program). Structural modeling has been performed, however, which shows that the center manway could be enlarged up to a 7-foot-diameter opening to allow deployment of large equipment (e.g., Marconaflo pump or Houdini [FERMCO 1995]).

Scenarios which required flooding of the silos were excluded from consideration based on the impracticalities of the resultant hydraulic pressure against the silo walls and possible leakage of contamination from the silo walls during retrieval operations. Additionally, due to the height of the silo walls, alternatives utilizing either a vacuum system for slurry removal or a remotely mounted centrifugal pump were not evaluated due to the impracticable high suction lift requirements.

Further, any alternatives that require the use of an articulated arm reaching out 40 feet from the center manway were not evaluated. Based on the current technology development status of this alternative, it was concluded that these alternatives would result in unacceptable project risk and involve relatively high capital costs.

Seven alternatives for hydraulic retrieval were considered, and the following is a description of each scenario along with a list of advantages and disadvantages developed through the evaluation of each scenario against the criteria discussed in Section 3. All scenarios consider the use of a silo superstructure for support of equipment over the silo with an equipment room mounted on the superstructure for equipment protection and to help provide radiological containment. Quantities and flow rates discussed in these scenarios are provided only as general representative estimates of the actual values. These values will be further developed and refined during both the conceptual and detailed design phases.

4.2.1 Scenario No. 1

Scenario No. 1 (Figure 4-2) utilizes the existing submersible hydraulic mining pump (the PO-92 Marconaflo) installed in the center of the silo and supported by an overhead structural steel superstructure. The pump is lowered into the silo by an overhead electric hoist attached to the superstructure. The pump has integral spray rings for agitating the residue at the pump suction and has a rotating submerged jet nozzle that is rotated slowly through a 360 degree arc for removal of the residue at some distance from the pump. The pump discharges approximately 140 gpm of slurry through a flexible hose to the top of the silo, where it enters double-walled piping for transportation to the FRVP for solids settling. The recycle water from the FRVP, after removal of solids, is pumped back to the silo at 135 gpm, where it is valved to the submerged jet nozzle or to one of the spray rings.

The removal operation will be controlled remotely and monitored using pressure, flow, and density instruments, and in situ cameras with integral lights. The slurry level in the silo will be monitored manually via the cameras. A high level switch mounted to the pump will help prevent submersion of the Marconaflo electric actuated valves. The following are advantages and disadvantages of this scenario:

Effectiveness - 2

- submerged jet may not have sufficient energy to reach silo wall resulting in incomplete residue removal
- limited ability to direct coarse material to center of silo for pumping
- limited ability to handle discrete objects: move with submerged jet, backflush pump or vertical Houdini deployment

Reliability - 4

+ simple equipment of mature design and relatively low mechanical complexity
+ equipment has been successfully used for mining applications and on similar projects

Safety, Containment, Exposure - 4

+ design requires no significant personnel activity on silos within radiation fields unless pump fails or Houdini is required
+ no transfer of equipment required between manways

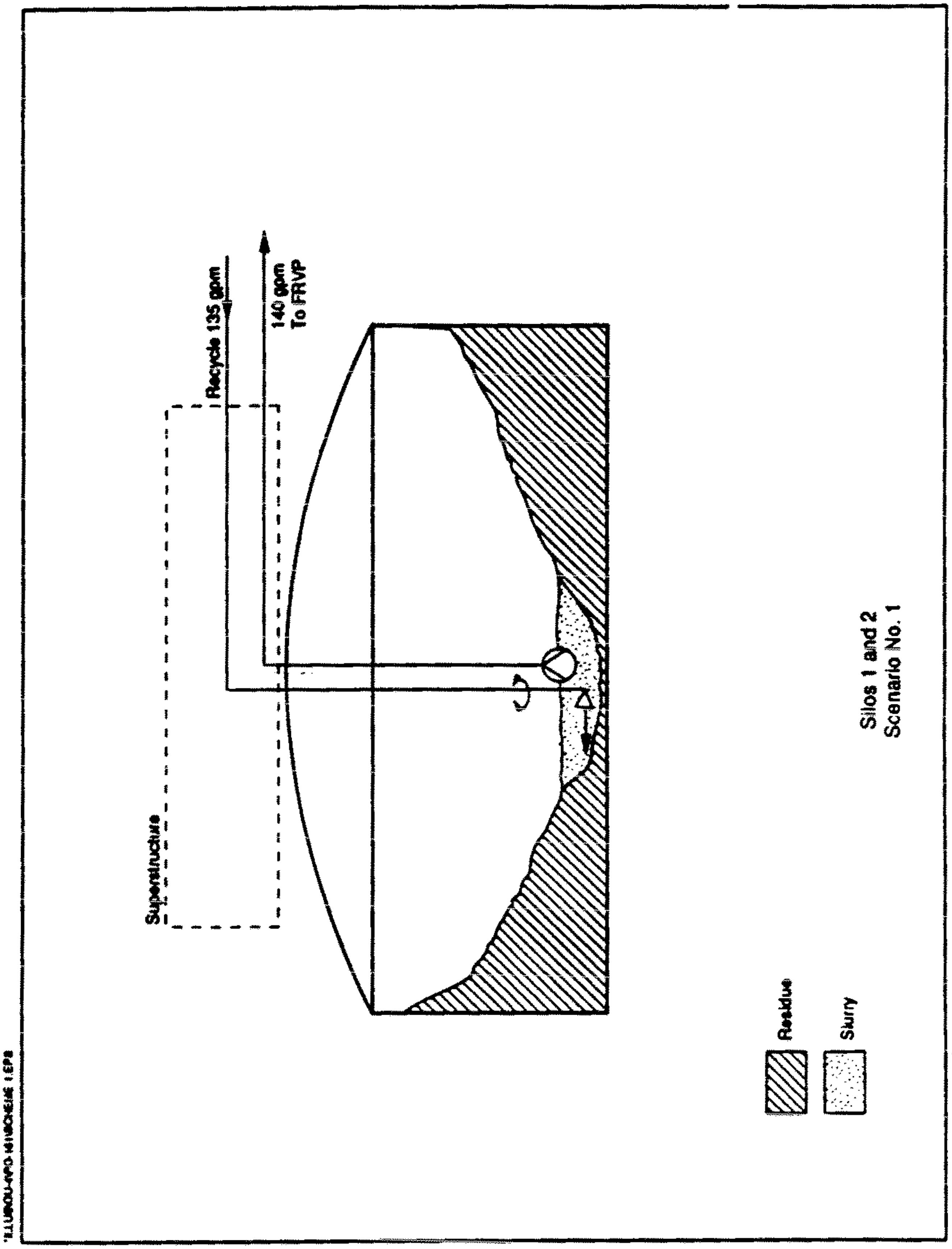


Figure 4-2 - Silos 1 and 2, Scenario 1

Cost - 5

+ equipment consists of relatively standard components
+ same silo entry requirements as Houdini
+ low equipment cost (existing Marconaflo pump can be used)

D&D Usefulness - 2

- equipment not suitable for decontamination of silo walls

4.2.2 Scenario No. 2

Scenario No. 2 (Figure 4-3) incorporates a 10,000-gpm submersible mixer pump for removal of the residue, and an additional submersible pump that will discharge 140 gpm of slurry through a flexible hose to the top of the silo, where it will enter double-walled piping for transportation to the FRVP for solids settling. The recycle water, after removal of solids, is pumped back to the silo at 135 gpm. The pumps are lowered into the silo through a center opening in the dome by overhead electric hoists attached to an overhead superstructure.

The removal operation will be controlled remotely and monitored using pressure, flow, and density instruments, and in situ cameras with integral lights. The slurry level in the silo will be monitored manually via the cameras. The following are advantages and disadvantages of this scenario:

Effectiveness - 3

+ high energy input from mixer maintains residue particles in slurry
- limited cleaning radius of submerged mixer jet may result in incomplete residue removal
- limited ability to transport coarse material to center of silo for pumping
- vertical Houdini deployment for discrete object retrieval difficult with two other pieces of equipment in silo

Reliability - 4

+ simple equipment of mature design, low mechanical complexity

Safety, Containment, Exposure - 4

+ no significant personnel activity on silos within radiation fields unless pump or mixer fails
+ no transfer of equipment required between manways

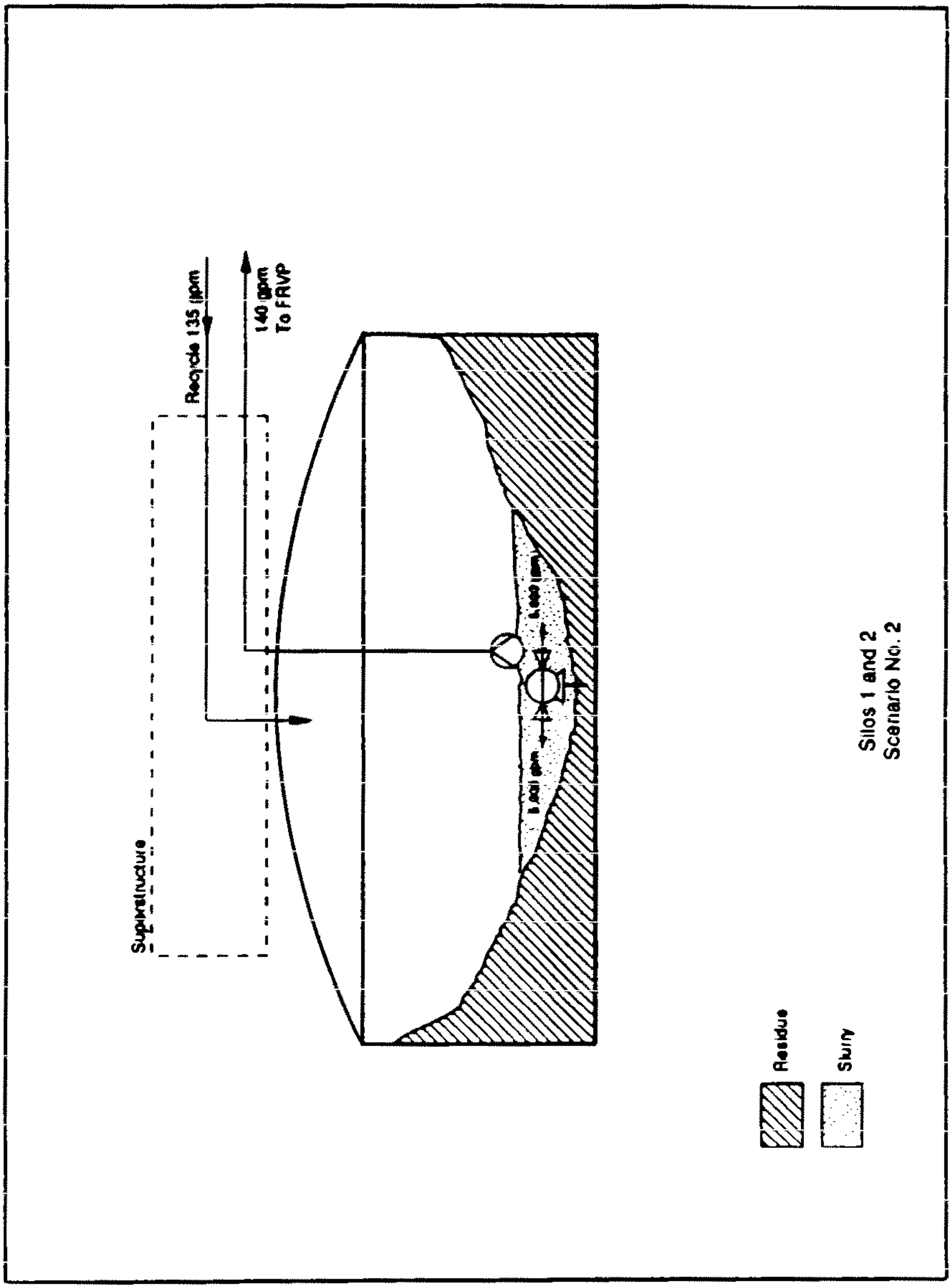


Figure 4-3 - Silos 1 and 2, Scenario 2

Cost - 3

+ equipment consists of standard items
+ same silo entry requirements as Houdini
- moderate equipment costs for large submersible mixers

D&D Usefulness - 2

- equipment is not suitable for decontamination of silo walls

4.2.3 Scenario No. 3

Scenario No. 3 (Figure 4-4) incorporates the same concept as Scenario No. 1, with the exception that the jet nozzle is mounted above the pump and is not submerged in the residue. The following are advantages and disadvantages of this scenario:

Effectiveness - 2

+ unsubmerged jet can reach silo wall providing better residue removal than Scenario 1
- limited ability to handle discrete objects: backflush pump or vertical Houdini deployment
- limited ability to direct coarse material to center of silo for pumping
- unsubmerged jet unable to sweep 360 degrees due to pump obstruction
- limited ability to slurry material in the immediate vicinity of the pump

Reliability - 4

+ simple equipment of mature design, low mechanical complexity
+ equipment has been successful for mining applications and on relatively similar projects

Safety, Containment, Exposure - 4

+ no significant personnel activity on silos within radiation fields unless pump fails
+ no transfer of equipment required between manways

Cost - 4

+ equipment consists of standard items
+ same silo access requirements as Houdini
+ low total equipment cost (although existing Marconaflo pump would need to be modified)

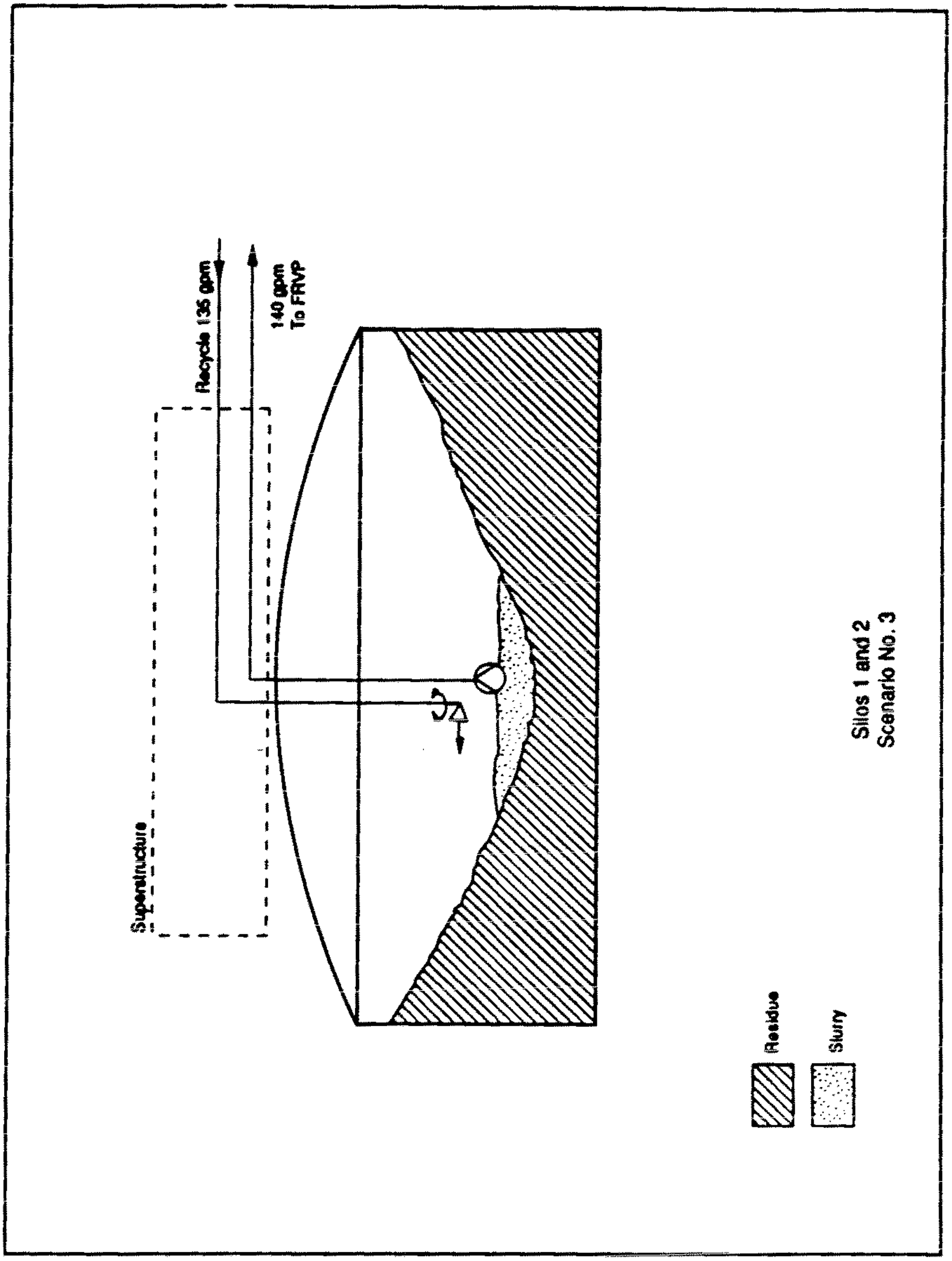


Figure 4-4 - Silos 1 and 2, Scenario 3

D&J Usefulness - 3

- unsubmerged jet has limited usefulness for decontamination of silo walls since it is integral with the pump

4.2.4 Scenario No. 4

Scenario No. 4 (Figure 4-5) replaces the submersible hydraulic mining pump used in Scenario 1 with a submerged jet pump and retains the unsubmerged, remote-controlled jet nozzle. The jet pump requires the addition of a batch tank to accommodate the high flow rate. A pump associated with the batch tank will discharge approximately 140 gpm of slurry through double-walled pipe to the FRVP. The following are advantages and disadvantages of this scenario:

Effectiveness - 3

+ unsubmerged remote controlled jet can reach silo wall, better residue removal than Scenario 1
- limited ability to direct coarse material to center of silo for pumping
- limited ability to handle discrete objects: backflush pump or vertical Houdini deployment

Reliability - 4

+ simple equipment of a mature design (simpler than centrifugal pump), low mechanical complexity, however, requires additional equipment (batch tank and external pumps)
+ equipment has been successful for similar mining applications and on relatively similar projects

Safety, Containment, Exposure - 2

+ no transfer of equipment required between manways
+ no significant personnel activity on silos within radiation fields unless pump fails
- more potentially contaminated equipment located outside silos require containment and monitoring
- batch tank and pumps require maintenance, increased personnel exposure

Cost - 3

+ same silo access requirements as Houdini
+ equipment consists of standard items
- moderately high total equipment cost (includes batch tank and additional pumps)

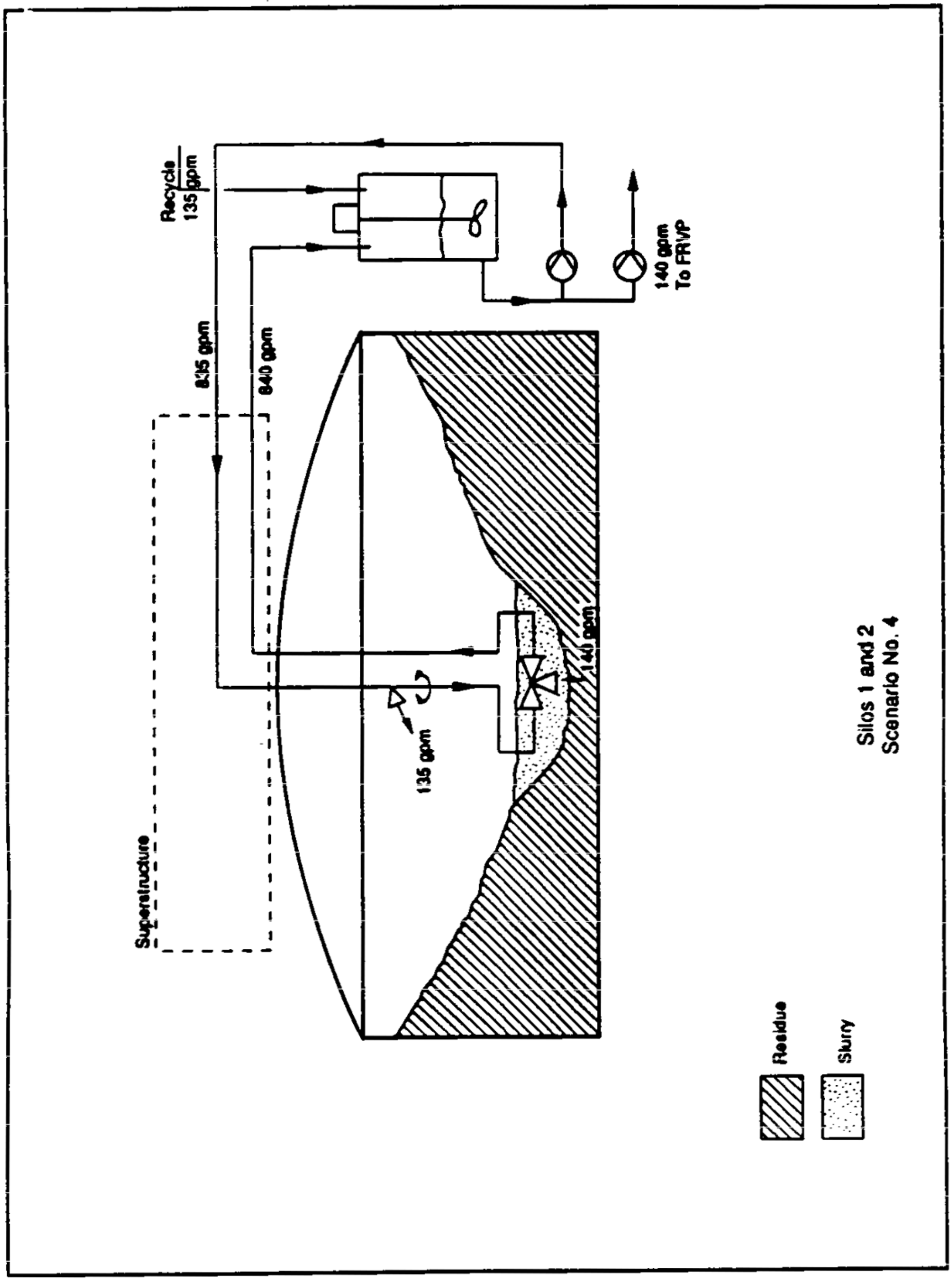


Figure 4-5 - Silos 1 and 2, Scenario 4

D&D Usefulness - 3

- unsubmerged jet has limited usefulness for decontamination of silo walls since it is integral with the pump

4.2.5 Scenario No. 5

Scenario No. 5 (Figure 4-6) incorporates a 2,000-gpm vertical centrifugal pump with an integral jet nozzle. The pump is mounted on a slewing ring on the overhead superstructure, and its unsubmerged jet nozzle is rotated slowly through a 360-degree arc for removal of the residue at some distance from the pump. A second submersible pump will discharge 140 gpm of slurry through a flexible hose to the top of the silo, where it will enter double-walled piping for transportation to the FRVP for solids settling. The recycle water, after removal of solids, is pumped back to the silo at 135 gpm.

The removal operation will be controlled remotely and monitored using pressure, flow, and density instruments, and in situ cameras with integral lights. The slurry level in the silo will be monitored manually via the cameras. The following are advantages and disadvantages of this scenario:

Effectiveness - 3

+ unsubmerged jet can reach silo wall, better residue removal than Scenario 1
- limited ability to direct coarse material to center of silo for pumping
- limited ability to handle discrete objects: backflush with pump
- Houdini deployment limited by other equipment in silo

Reliability - 3

+ selected equipment utilizes a mature technology
- more complicated equipment design, higher mechanical complexity and inherent maintenance

Safety, Containment, Exposure - 4

+ no transfer of equipment required between manways
+ no significant personnel activity on silos within radiation fields, unless pump fails

Cost - 2

+ same silo access requirements as Houdini
- moderate equipment cost based on complexity and specialized design

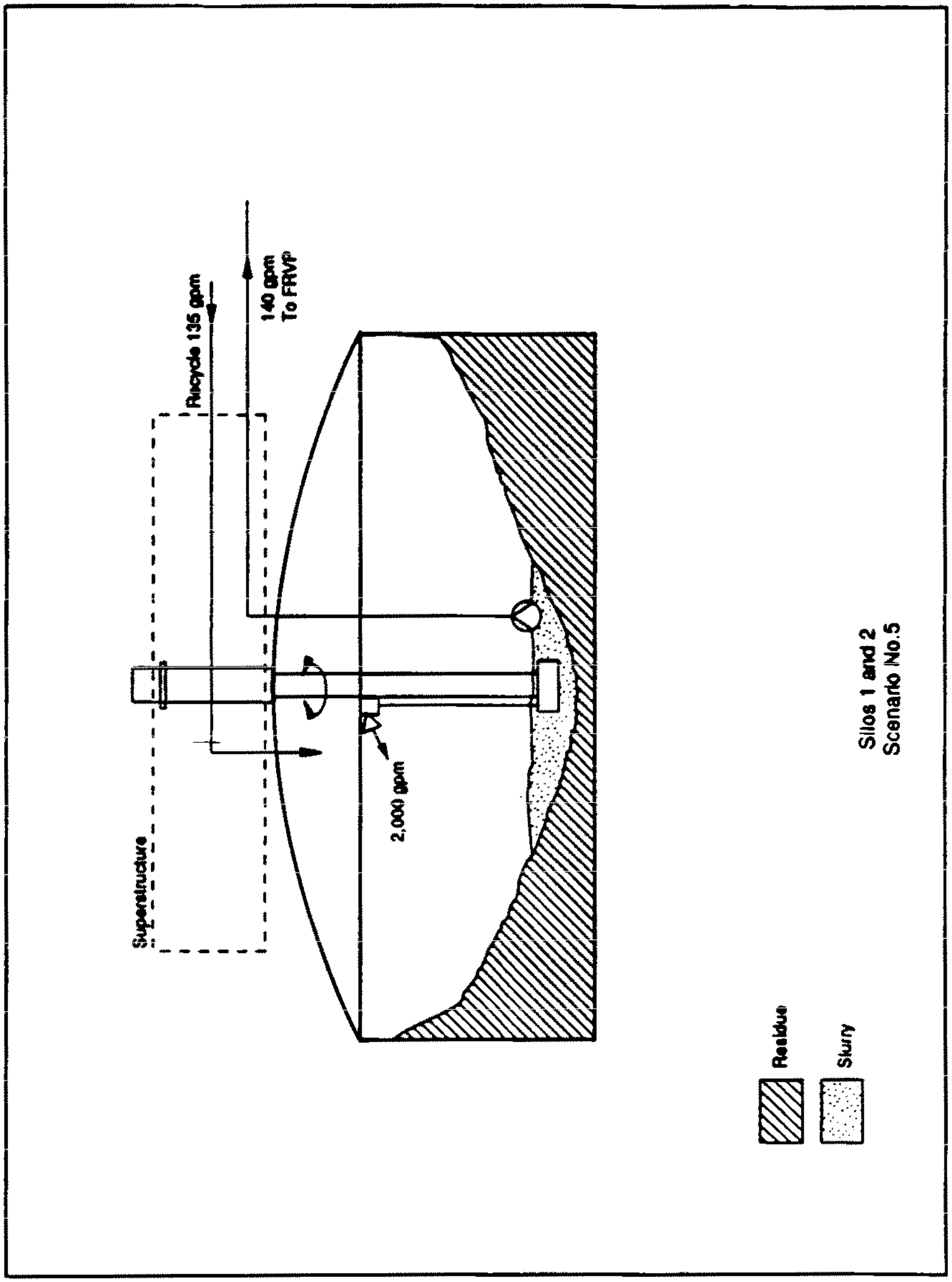


Figure 4-6 - Silos 1 and 2, Scenario 5

D&D Usefulness - 5

+ equipment can be used for both heel removal and decontamination of silo walls

4.2.6 Scenario No. 6

Scenario No. 6 (Figure 4-7) incorporates four small submersible pumps installed through the four outer manways in the top of the silo. The four pumps discharge a total of 140 gpm of slurry through double-walled pipe to the FRVP, while 135 gpm is recycled back to the silo and injected by an unsubmerged, remotely controlled single-point sluice jet nozzle. The pumps can be operated individually or in groups. The following are advantages and disadvantages of this scenario:

Effectiveness - 4

+ provides for effective residue removal out to silo walls using dome mounted nozzle
+ better ability to transport coarse material to pumps due to the relative location of jet and more places to transport it to (i.e., four pumps) and less distance to travel
- limited ability to deal with discrete objects: backflush pumps, and no entry by Houdini until heel removal

Reliability - 4

+ simple, mature equipment design, low mechanical complexity
+ four pumps provide redundancy (no redundancy on jet)

Safety, Containment, Exposure - 3

+ no transfer of equipment between manways
+ no significant amount of personnel activity required on silos unless equipment fails
- requires an equipment room type containment arrangement at each of four pump deployment locations
- less ability to control slurry level in silo due to non-distinct slurry pockets

Cost - 3

+ equipment consists of standard catalog items
+ lighter superstructure loads and no need for initial manway enlargement; however, center manway must eventually be enlarged for Houdini and discrete object retrieval
- requires access and equipment support over all five manways

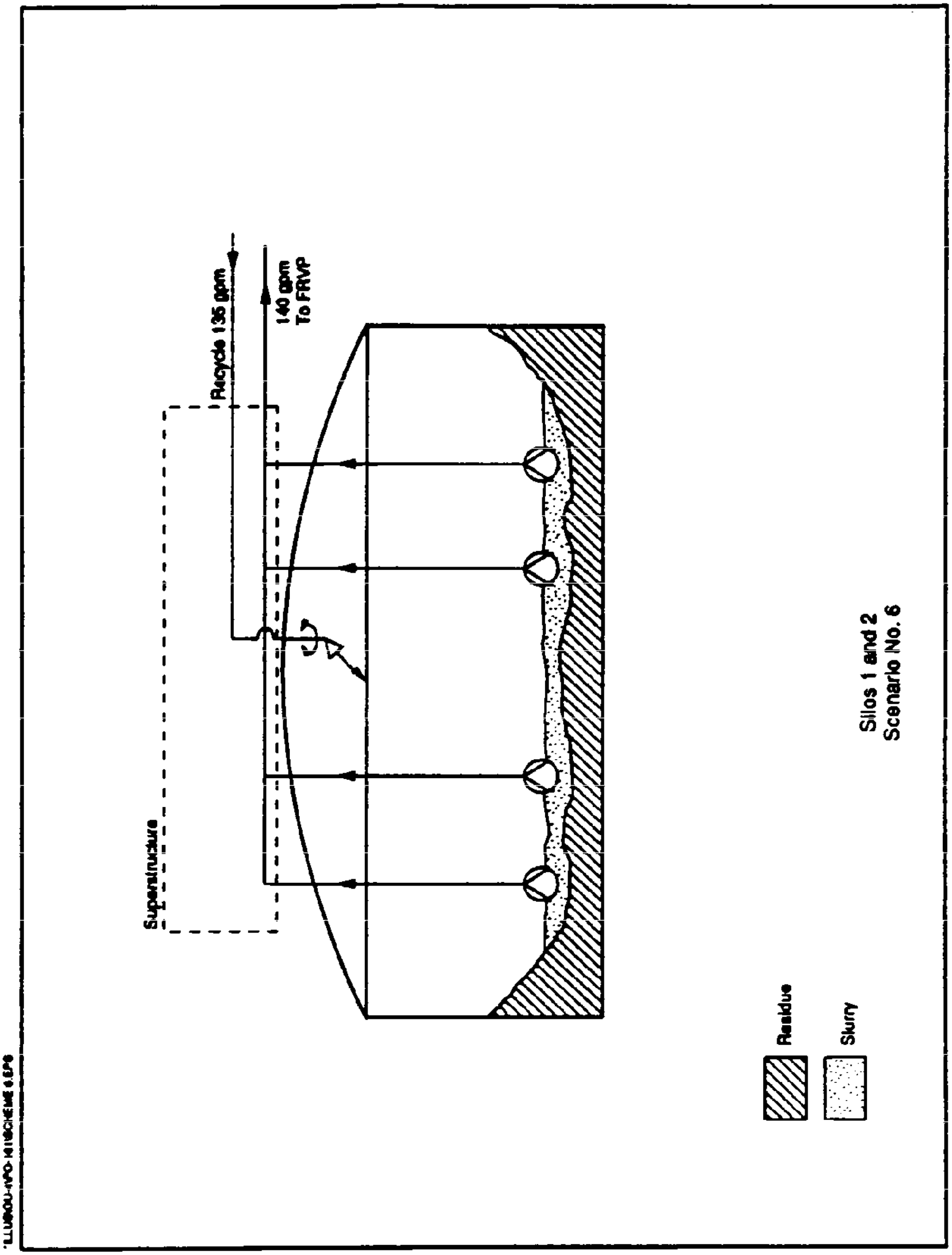


Figure 4-7 - Silos 1 and 2, Scenario 6

D&O Usefulness - 4

+ equipment can be used for decontamination operations
+ dome-mounted unsubmerged jet could be used for decontamination of Silo 3 walls (if determined feasible)

4.2.7 Scenario No. 7

Scenario No. 7 (Figure 4-8) is identical to Scenario No. 1, with the addition of two unsubmerged, remote-controlled, single-point sluice jet nozzles, located 180 degrees apart in the existing silo openings. The following are advantages and disadvantages of this scenario:

Effectiveness - 5

+ two unsubmerged jets can reach silo wall, better at reaching all areas of silo for bulk and heel residue removal
+ best ability to direct coarse material to pump at center of silo from jet nozzles mounted in outer manways
+ better ability to handle discrete objects: blast with unsubmerged jets and submerged jets, backflush pump or vertical Houdini deployment

Reliability - 4

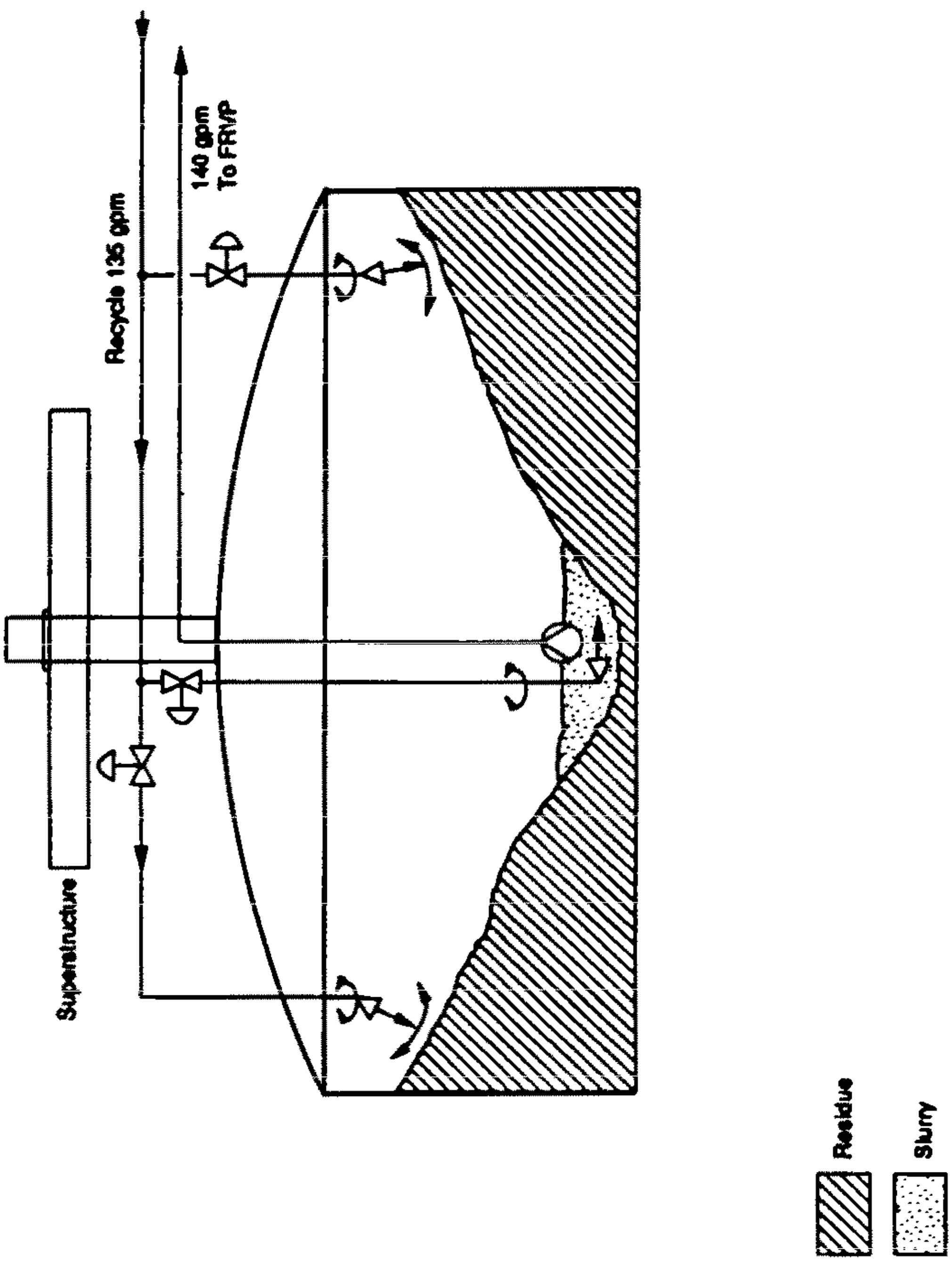
+ simple equipment of mature design, low mechanical complexity
+ equipment has been used successfully on similar projects
+ redundancy on jets

Safety, Containment, Exposure - 4

+ no significant personnel activity within radiation fields unless equipment fails
+ no anticipated transfer of equipment required between manways

Cost - 2

- moderate equipment cost for spray jets, equipment consists of standard items (purchased Marconaflo pump can be used)
- requires access through enlarged center dome manway plus two outer manways



Silos 1 and 2
Scenario No. 7

D&D Usefulness - 5

- + two unsubmerged jets very useful for decontamination of silo walls due to range and independence from pump
- + dome-mounted unsubmerged jets could be used for decontamination of Silo 3 walls (if determined feasible)

4.3 Recommended Alternative

Scenario No. 7 is the recommended process for removal of the K-65 residues because it is a proven, simple technology that uses standard equipment and delivers the required removal capacity with a large effective cleaning radius. The design concept will be fully developed to address contamination control requirements and personnel safety, and to limit any potential damage to the silo. Both the Marconaflo pump and single-point sluice jets are proven for industrial use for similar applications. The combination of these two technologies provides the most flexible, proven design relative to the evaluated alternatives for hydraulic removal from Silos 1 and 2.

Tables 4-2 and 4-3 list of the major pieces of equipment required for the recommended alternative above and beyond what would otherwise be required for deployment of Houdini for discrete object and heel removal through an enlarged center manway. A relative order of magnitude cost is provided for each piece of recommended equipment along with an estimated lead time for procurement. The equipment identified for the recommended alternative largely includes standard catalog items or equipment already available which will not require specialized design, modification, or manufacture.

Table 4-2 - Silo 1 Recommended Residue Retrieval Equipment

Equipment Description	Capital Cost	Lead Time (weeks)
7.5 hp Marconaflo Slurry Pump w/ 0.25 hp jet	$0 (existing)	0
Single-Point Sluice Jets (two required)	$203,200 (total)	18
2-ton (3 hp) Pump Tilt Hoist	$3,500	8

Table 4-3 - Silo 2 Recommended Residue Retrieval Equipment

Equipment Description	Capital Cost	Lead Time (weeks)
7.5 hp Marconaflo Slurry Pump w/ 0.25 hp jet	$100,000	20
Single Point Sluice Jets (two required)	$203,200 (total)	18
2-ton (3 hp) Pump Tilt Hoist	$3,500	8

The combined associated costs for the primary removal equipment for Silos 1 and 2 is estimated to be less than $600,000. The maximum lead time associated with this equipment should not exceed 20 weeks. The equipment costs for several of the other alternatives considered by this study would be significantly less without the addition of the unsubmerged jets for Scenario 7, which will cost approximately $200,000 per silo. It is the conclusion of this study, however, that the additional effectiveness and flexibility added by the incorporation of these jets fully warrants the additional cost.

Development of the recommended equipment will proceed with the conceptual design in PO-161, which will include more detailed equipment descriptions and catalog cuts, where applicable.

4.4 Recommended Testing and Activities

4.4.1 Slurry Rheology

Slurry rheology data of the actual silo residue is needed for the generation of the slurry pipeline pressure drop calculations and subsequent slurry pump sizing. It is anticipated that these data will become available through operation of the VITPP. If these data are not available at the time of the FRVP design, however, conservative assumptions will be required. It is assumed by this study that the 70 feet of total dynamic head specified for the Marconaflo pump is adequate to pump the K-65 slurry from the silos. If sufficient rheology data is not available to confirm the suitability of the Marconaflo pump, then testing of the Marconaflo pump on surrogate slurry is recommended.

4.4.2 Solids Settling

Additional solids settling tests with actual residue samples from the silos should be performed. The samples should be mixed with various concentrations of bentonite clay to simulate the performance of the thickener, since bentonite clay is known to inhibit solids settling. Flocculants should be added to aid settling of slurry/BentoGrout combinations. It is anticipated that these data will become available through operation of the VITPP. If those data are not available at the time of the FRVP design, however, conservative assumptions will be required.

SECTION 5

PNEUMATIC RETRIEVAL OF METAL OXIDES

The residue in Silo 3 is a dry, loose powder of free-flowing material yielding angle-of-repose measurements of 20 degrees and 30 degrees, respectively (Stone 1995). The residue has a moisture content of 3.7 percent to 10.2 percent and has a mean particle size of less than 22 microns (IT 1990). It appears that the residue will be easily conveyed from the silo with a vacuum pneumatic transport system since the residue consists of very fine particles. Table 5-1 and Figure 5-1 present the grain size distribution of typical Silo 3 material. Greater than 90 percent (by weight) of the residue is finer in size than 50 microns (finer than sand). The precise fine fraction (< 14 microns) is currently unknown due to apparent problems with the hydrometer analysis (i.e., the particles would not settle). This condition is shown clearly in Figure 5-1. Additional analyses are currently underway to better identify the fines fraction. Results will be incorporated into the Residue Retrieval System design when available. This powdery residue presents an airborne risk for release during retrieval and transport. Confinement during retrieval will be achieved by keeping the silo at a negative pressure by exhausting air from the silo through a HEPA filtration system. Confinement during transport will be accomplished by a vacuum pneumatic transport system.

The residue in the silo should be very flowable; in fact, due to the small particle size, it may even be floodable, with sufficient aeration. The major problem with residue retrieval in this silo is physically getting the vacuum suction hose to all of the residue remotely. In addition, tramp material in the silo may cause problems with the vacuum retrieval system (e.g., plastic glove bags or rags will plug the vacuum pickup nozzle). A specially designed nonflooding vacuum nozzle with an integral coarse screen will be used to prevent the line from plugging with residue as well as tramp material (see Figure 5-2). This design nozzle can actually be submerged in the residue material without the danger of line plugging due to solids overfeeding, and it can remove any tramp plastic residue material by simply pressurizing the vacuum hose and blowing the plastic from the nozzle. Compressed air jets will be secured to the end of the vacuum nozzle to add fluidity to the residue and to break any agglomerates. Alternatively, a rotating screw auger may be used to assist in removing the residues and injecting them into the pneumatic transport system. The auger will be more effective in reclaiming compacted and possibly agglomerated materials. If residue bridging problems do occur due to an unexpectedly high angle of repose, the residue could be aerated prior to retrieval to eliminate the bridging problem and allow the residue to form a low angle of repose. The aeration would be accomplished by inserting an air hose with an integral multiple head spray nozzle into existing silo openings. Local aeration would be accomplished by introducing high passive air through air jets mounted adjacent to the vacuum nozzle.

Table 5-1 - Silo 3 Sample Analysis Results (IT 1990)

Sieve Size/Time	Diameter (mm)	Percent Passing by Weight
Sieve Analysis		
3.000 in	75.000	100.0
1.500 in	37.500	100.0
0.750 in	19.000	100.0
0.375 in	9.500	100.0
No. 4	4.750	100.0
No. 10	2.000	100.0
No. 20	0.850	99.7
No. 40	0.425	97.7
No. 60	0.250	96.0
No. 140	0.106	93.5
No. 200	0.075	93.2
Hydrometer Analysis		
1 min	0.045	92.4
2 min	0.033	85.3
5 min	0.022	67.5
15 min	0.014	35.5
30 min	0.010	35.5
60 min	0.007	35.5
240 min	0.004	35.5
1440 min	0.001	35.5

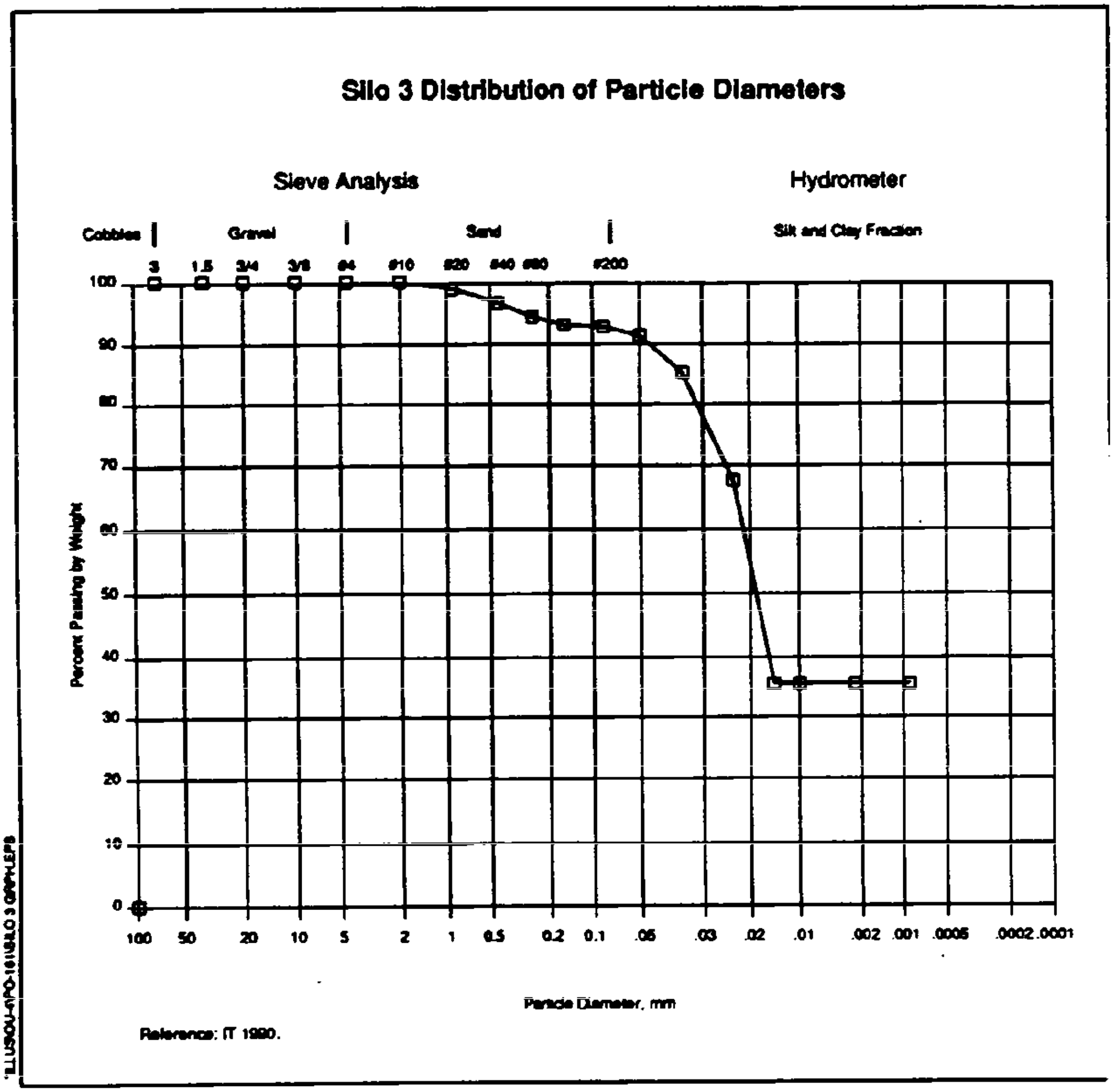
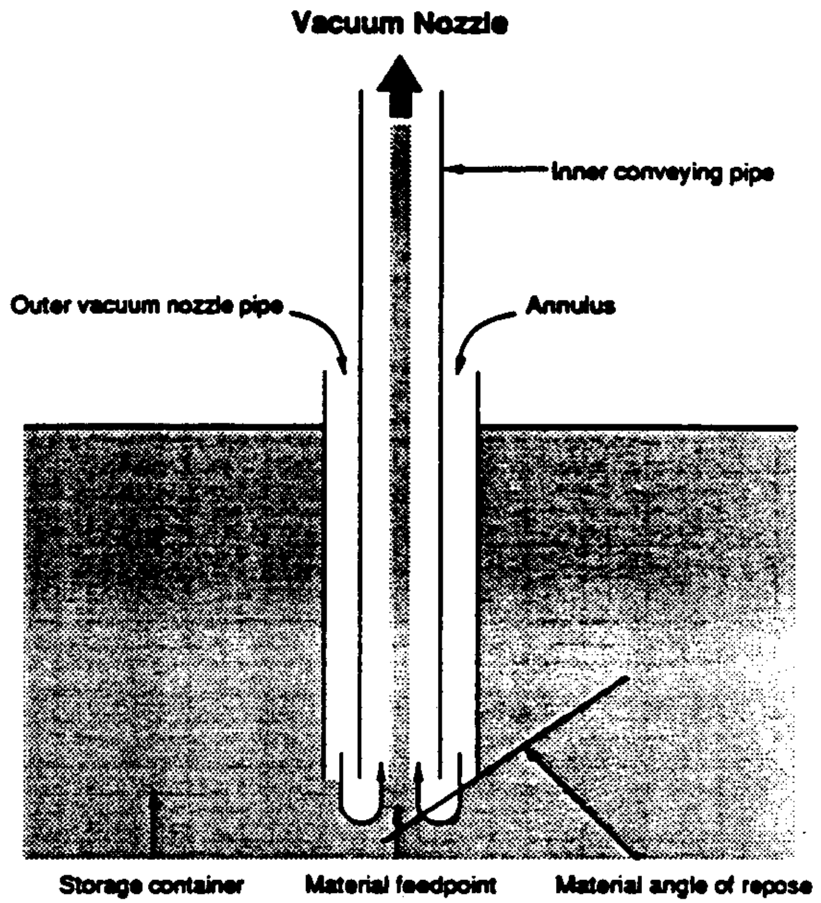


Figure 5-1 - Silo Distribution of Particle Diameters



ILLUS\OU-4\PO-161\VAC NOZZLE.EPS

Figure 5-2 - Vacuum Nozzle

The Silo 3 pneumatic retrieval system will support the FRVP glass production of 24 tons per day as given in the DCP (DOE 1995d). Based on the glass formulation given in the DCP (DOE 1995d), which includes K-65 residues, Silo 3 residues and additives (actual 18.54 pounds Silo 3 per 100 pounds glass), and assuming the system will operate one shift per day (assume 4 hours actual transfer time), the retrieval system must transfer 2,390 lbs/hr of Silo 3 material. A second glass formulation, which uses Silo 3 material only, plus additives, requires 82 lbs of Silo 3 material per 100 lbs of glass. To support either glass formulation, the conceptual vacuum retrieval system will be rated at 3,500 lbs/hr of Silo 3 solids. This rate will allow residue retrieval for the first formulation in one shift, but will require two shift removal operations (11 hrs) for the second formulation. Double-walled piping will be used to provide secondary containment where required.

5.1 Discrete Object and Heel Removal

All scenarios evaluated assume the use of a reconfigurable in-tank mobile robot (Houdini) for discrete object and heel removal. Houdini is presently under development by RedZone Robotics, Inc., for the DOE, Morgantown Energy Technology Center (RedZone 1995). Except for Scenario 1, Houdini will be lowered into Silo 3 through an enlarged manway by its tether. Scenarios 2 and 5 use an outer manway (and smaller superstructure), while Scenarios 3 and 4 use the center manway for deployment.

During bulk retrieval operations, it is unknown whether Houdini will be supported sufficiently by the powdery residue to operate on its surface. During this time, however, Houdini may be of limited usefulness due to its ability to be lowered into the silo to retrieve or manipulate objects in the immediate vicinity of the manway using its manipulator arm while hanging in an overhead position.

Following bulk retrieval, after the silo floor is nearly or partially uncovered, Houdini will be able to operate more freely within the silo to perform heel removal and additional discrete object removal. Houdini can use its hydraulically powered manipulator arm to hold a vacuum tube as well as a number of other tools to perform local, mobile heel removal. Objects can also be secured, using Houdini's manipulator, and transported to the center of the silo, where the objects can be retrieved.

Regarding the future D&D of the silo, some of the residue will likely adhere to the silo walls. Since this residue is radioactive, very dry, and has a very small average particle size, it poses a severe airborne release problem during the demolition of the silo. Houdini will be able to remove the respirable dust from the silo floor, but not from the silo walls or roof. Therefore, it appears this residue must be removed prior to demolition. Although it currently appears that none of the Silo 3 scenarios are effective for decontamination of the silo walls, a supplemental process and its associated equipment will be identified during development of the D&D Plan under PO-161.

5.2 Pneumatic Retrieval Alternatives

As discussed previously, for Silo 3, this letter report is limited to evaluating various configurations of pneumatic retrieval. This arrangement consists of a vacuum pneumatic transport system that conveys the residue solids out of the silo to a filter/receiver that disengages the solids from the air stream and directs the solids out of the filter/receiver through a rotary airlock to the FRVP pneumatic transport system. The air is filtered before leaving the filter/receiver and is directed back to the silo or discharged to the atmosphere through appropriate High-Efficiency Particulate Air filters (and carbon, if determined necessary for radon control).

Five alternatives for residue removal were qualitatively evaluated. The following is a description of each scenario along with a list of the advantages and disadvantages developed through the evaluation of each scenario against the criteria presented in Section 3.

5.2.1 Scenario No. 1

Scenario No. 1 (Figure 5-3) incorporates mechanically assisted vacuum retrieval devices inserted into two new penetrations at grade level located 180 degrees apart in the side walls of the silo. Because Silo 3 is a post-tensioned structure, the new penetrations will require the application of a back plate and banding of the silo wall prior to cutting. A sliding seal is used to maintain confinement in case the residue material is floodable. Initially, mechanical augers are inserted several feet through new silo penetrations. The augers feed the pneumatic transport system and lower the residue level in the silo. Once the level is lowered sufficiently, a vacuum tube is extended further into the silo to retrieve residue from the center area of the silo. Enclosures at the out base of the silo provide secondary containment for the retrieval equipment. The following are advantages and disadvantages of this scenario:

Effectiveness - 3

+ equipment is able to handle residue of varying consistency, and can deploy cutting/grinding tools if necessary
- provides limited visibility and subsequent monitoring of retrieval operations due to submerged nozzle operations
- provides limited ability to reach all areas of silo possibly leaving significant heel
- bridging of residues may occur

Reliability - 3

+ utilizes simple equipment of a mature design
+ two retrieval systems provide redundancy and backup

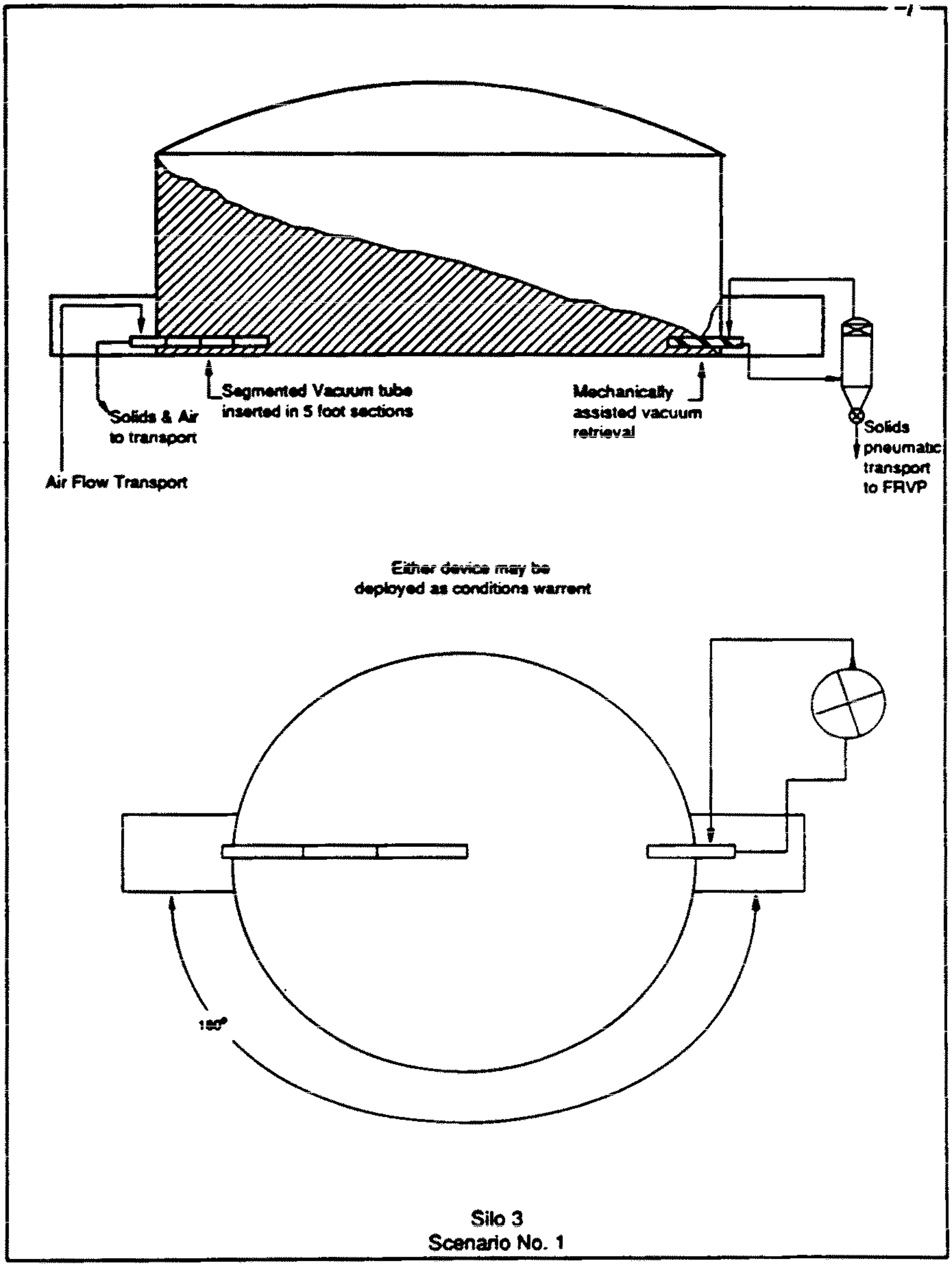


Figure 5-3 - Silo 3, Scenario 1

Safety, Containment, Exposure - 5

+ eliminates lifting operations over the silo for superstructure erection
+ no retrieval operations over dome reduces worker exposure, much easier to shield workers at grade level
- requires equipment room type containment system at silo wall for deployment of retrieval equipment

Cost - 4

+ center dome manway does not require enlargement
+ no superstructure required for bulk retrieval operations, or heel retrieval if Houdini enters at grade
- requires a second larger silo wall cut for Houdini access

D&D Usefulness - 3

- no superstructure available to support D&D operations

5.2.2 Scenario No. 2

Scenario No. 2 (Figure 5-4) incorporates the use of the existing 3-inch silo decant ports for insertion of vacuum tubes and air tubes to perform residue retrieval. The following are advantages and disadvantages of this scenario:

Effectiveness - 2

- smaller vacuum tubes are not able to handle residue of varying consistency
- provides limited visibility and subsequent monitoring during retrieval due to submerged nozzle operations
- provides limited ability to reach all areas of silo possibly leaving large heel
- residue may bridge leaving vacuum system ineffective

Reliability - 2

+ utilizes simple equipment of a mature design
+ multiple ports located 180 degrees apart provide limited redundancy
- small decant port size limits size of retrieval tools in silo for bulk retrieval; clumping or agglomeration would cause process upsets

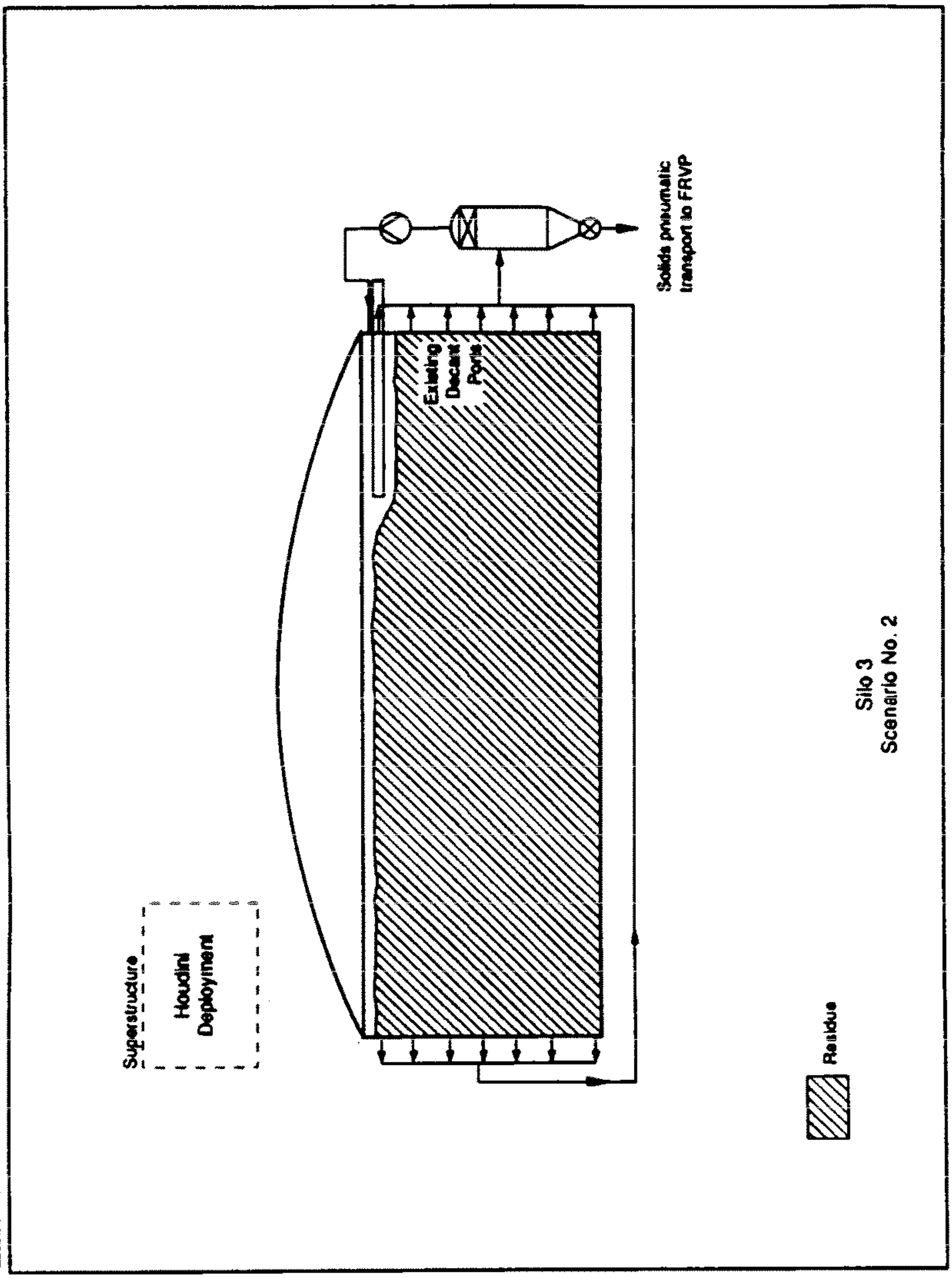


Figure 5-4 - Silo 3, Scenario 2

Safety, Containment, Exposure - 3

+ no significant personnel activity required on silo dome until heel removal
- requires multiple transfers of equipment between decant ports, involving setting and breaking containment multiple times

Cost - 4

+ uses only existing silo openings for bulk retrieval
+ superstructure is not needed for bulk operation, smaller superstructure could be used for Houdini deployment through enlarged outer manway or east hatch.

D&D Usefulness - 3

- no superstructure to support D&D operations

5.2.3 Scenario No. 3

Scenario No. 3 (Figure 5-5) incorporates the use of two overhead vacuum pipes sequentially inserted vertically down into the residue through the five existing silo roof penetrations. The vacuum pipes would be inserted into the silo in 5- to 6-foot increments in a "bag-in/bag-out" arrangement and advanced automatically as required. High air pressure could be used to aerate the immediate vicinity of the vacuum nozzle. The vacuum pipes would be operated one at a time to retrieve the residues in the area below each manway. The majority of operating time would occur on the first vacuum tube insertion, which would remove approximately 50 percent of the residue. The following are advantages and disadvantages of this scenario:

Effectiveness - 4

+ multiple medium sized vacuum tubes are able to handle residue of varying consistency
+ provides good visibility through manways not in actual use
+ aeration tubes can easily be inserted to improve flow characteristics
- somewhat limited ability to reach all areas of silo possibly leaving a significant heel (~20 percent of residue)

Reliability - 3

+ two tubes provide redundancy and backup although of a single technology
+ very simple technology, very low mechanical complexity
- clumping or agglomeration of residues could cause difficulties in retrieval and process upset

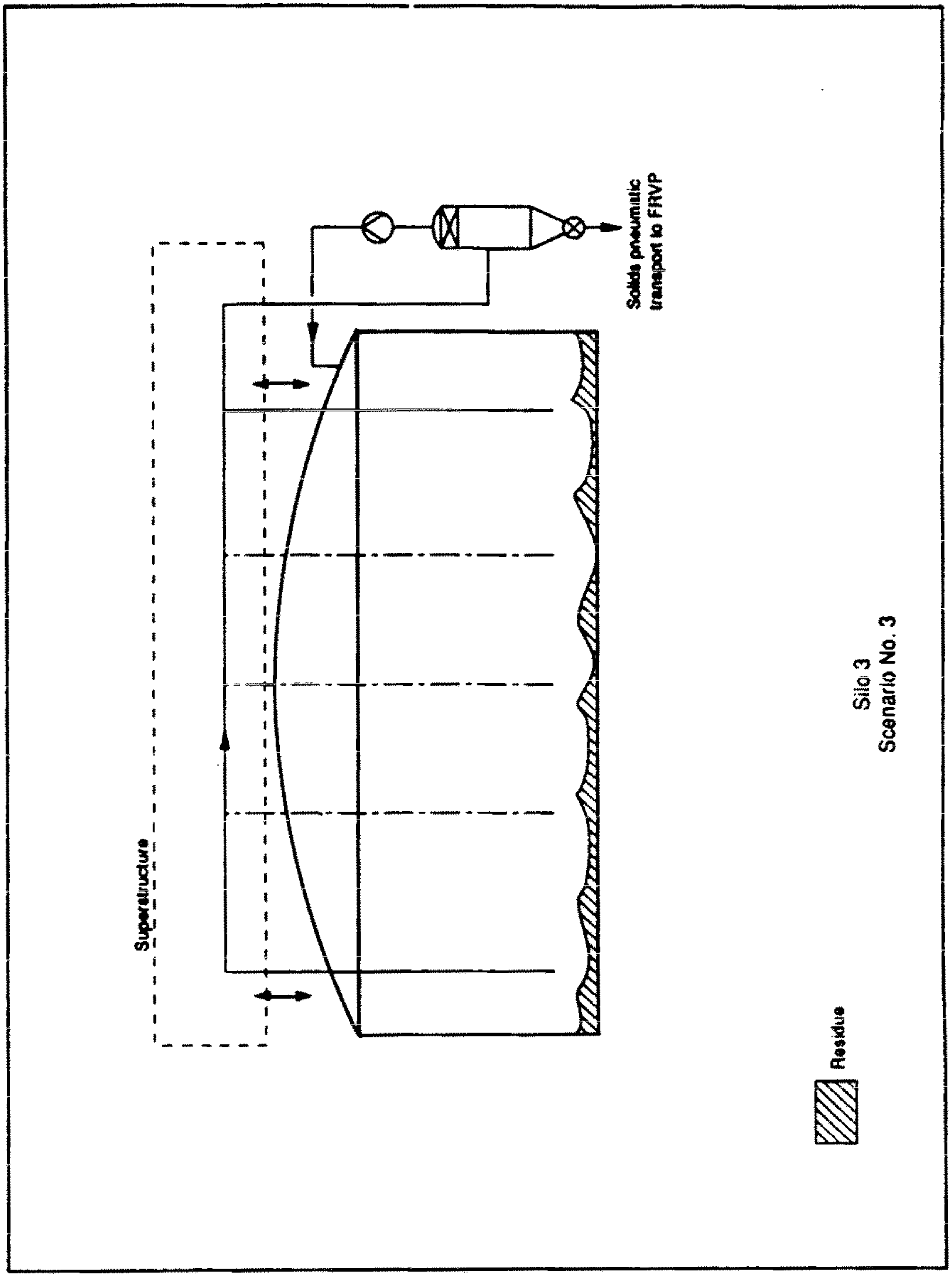


Figure 5-5 - Silo 3, Scenario 3

Safety, Containment, Exposure - 2

- requires limited but periodic personnel activity on silo dome to insert tube lengths and move tube insertion devices
- requires multiple operations requiring containment and ventilation

Cost - 2

+ inexpensive bulk retrieval equipment costs
+ uses only existing silo openings for bulk removal, but will require manway modification for center deployment of Houdini for heel removal
- requires a large superstructure accessing all five manways (including containments) for bulk operation

D&D Usefulness - 4

+ large superstructure could be used in support of D&D operations

5.2.4 Scenario No. 4

Scenario No. 4 (Figure 5-6) is similar to Scenario No. 3 except that it incorporates two remote-controlled articulated rotatable arms supporting a vacuum pickup nozzle in place of the vacuum pipes and that it only requires access to three of the manways. The two arms are inserted into the existing silo manways and are relocated as necessary to a third manway. The articulated arms are maneuvered (raised, lowered, and rotated) remotely. The following are advantages and disadvantages of this scenario:

Effectiveness - 5

+ multiple medium-sized vacuum tubes able to handle residue of varying consistency
+ provides good visibility through manways not in actual use
+ aeration tubes can easily be inserted to improve flow characteristics
+ articulation improves ability to reach silo interior reducing heel size

Reliability - 3

+ two sets of tubes provide redundancy and backup
- increased mechanical complexity of tube deployment equipment, inherent increase in required maintenance
- increased technological complexity due to articulation relative to simple vacuum tubes

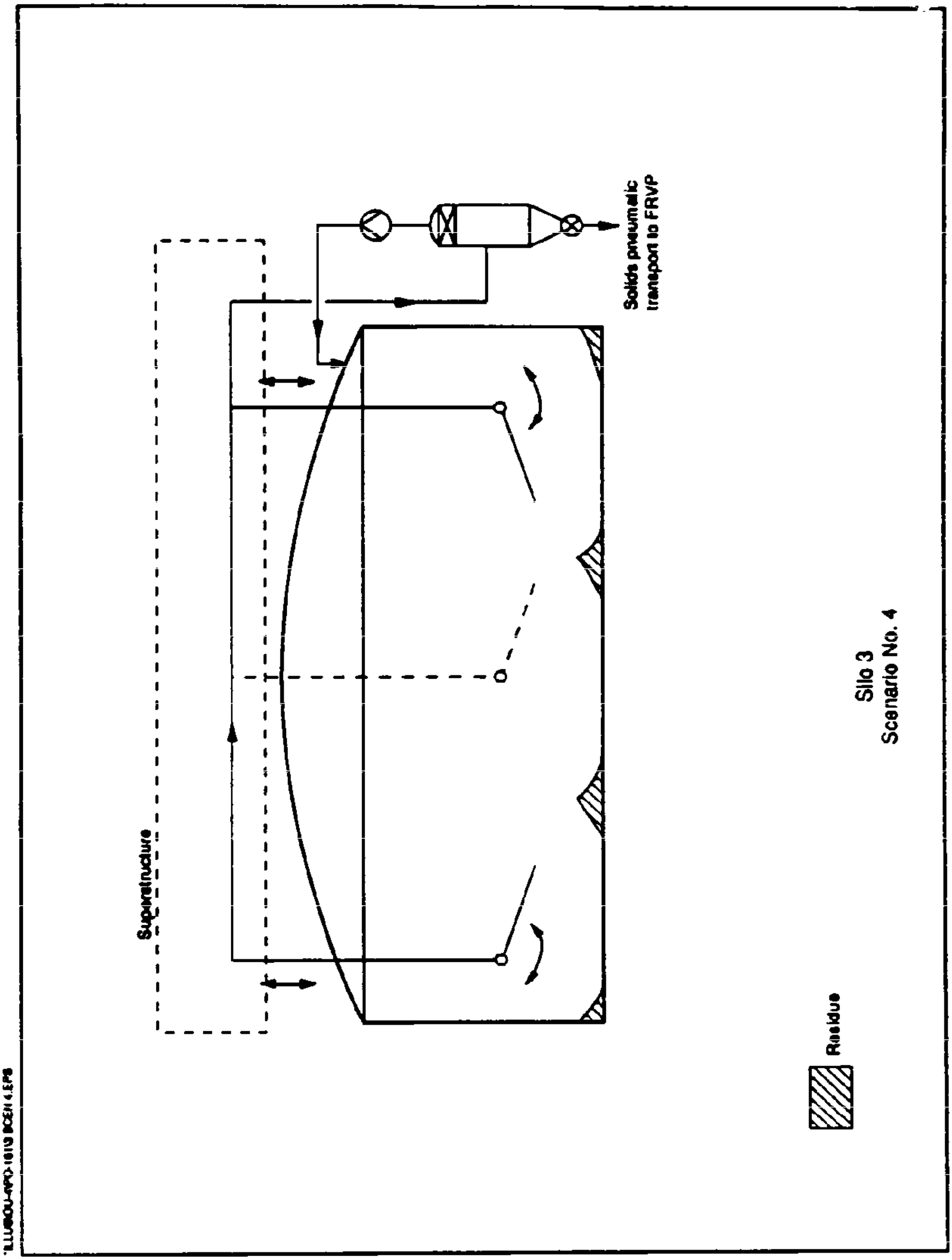


Figure 5-6 - Silo 3, Scenario 4

Safety, Containment, Exposure - 2

- requires limited but periodic personnel activity on silo dome to insert tube lengths
- requires transfer of vacuum tube arrangements between manways
- requires multiple operations involving containment

Cost - 3

+ uses only existing silo openings for bulk removal, but will require manway modification eventually for center deployment of Houdini for heel removal
- moderate equipment costs due to articulated arms and controls
- articulated, rotatable deployment equipment may require specialty equipment
- requires a large superstructure accessing three manways (including containments) for bulk operation

D&D Usefulness - 4

- superstructure could be used in support of D&D operations

5.2.5 Scenario No. 5

Scenario No. 5 (Figure 5-7) incorporates the use of Houdini or a similar maneuverable tracked vehicle to position a vacuum pickup nozzle for residue retrieval. An additional mobile robot will be required as a backup for the primary vehicle. Houdini is lowered through an enlarged silo manway at the east hatch via a support tower and its Tether Management and Deployment System. Since Houdini has its own hoisting system, control center, camera system, and hydraulic manipulator, additional equipment is not required. Houdini will be lowered continuously until an inverted cone is formed in the residue down to the silo floor. At this point, Houdini will crawl on the silo floor and maneuver the vacuum nozzle around the entire floor surface, thereby removing all of the residue. The following are advantages and disadvantages of this scenario:

Effectiveness - 5

+ provides excellent coverage of silo, leaving virtually no heel
+ able to handle residue of varying consistency due to mechanical abilities of Houdini
+ provides good visibility through outer manways and with robot camera
+ aeration tubes can easily be inserted to improve flow characteristics

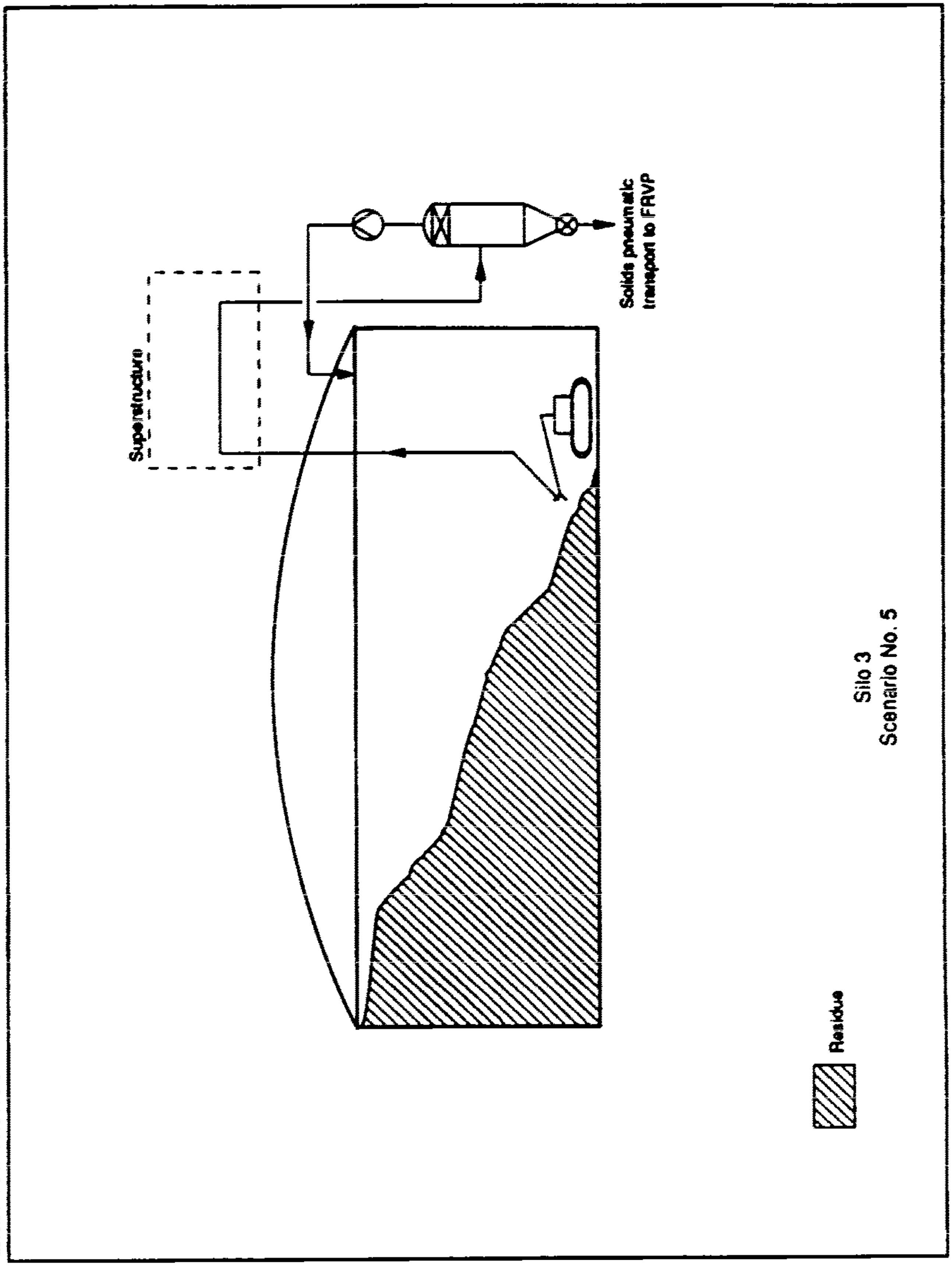


Figure 5-7 - Silo 3, Scenario 5

Reliability - 2

- a second robot vehicle must be purchased for redundancy of primary retrieval method
- increased mechanical complexity of robot system and inherent maintenance
- residue could flood and bury robot vehicle, possibly beyond retrieval
- Houdini is an unproven technology

Safety, Containment, Exposure - 4

+ due to its remote operation, requires only limited personnel activity on silo dome during installation and maintenance
+ entry into single manway reduces containment and ventilation requirements

Cost - 3

+ no additional cost for deployment of heel retrieval equipment
+ simplified superstructure accessing a single manway
- use of additional robot represents a significant equipment cost or limits the availability of Houdini for K-65 silo operations

D&D Usefulness - 3

- the support tower would likely be only of limited use during D&D operations since it would not span the silo

5.3 Recommended Alternative

Scenario No. 1 received the greatest score and is selected as the recommended retrieval configuration. Scenario No. 1 provides for adequate residue retrieval, although it leaves moderate sized heel following bulk retrieval. The primary advantage of this scenario is the fact that it does not require construction of a superstructure. This significantly reduces the cost over scenarios 3 and 4. Additionally, the absence of a superstructure significantly improves several safety aspects of the design by avoiding lifts of heavy equipment over the dome and eliminating the need for personnel to spend significant amounts of time over the dome performing operations and maintenance in a high-radiation field. Operations at grade will be easier to shield, easier to control, and easier to maintain.

Penetration at grade also allows the use of two different technologies. Although Houdini would not be inserted into the silo during the bulk retrieval, the use of both mechanical and pneumatic technologies as well as two retrieval ports provides adequate backup and redundancy in the case of process upset (i.e., management of non-retrievable objects) to ensure continued operations. Subsequent enlargement of the grade level opening for Houdini deployment following bulk retrieval will also be safer than enlargement of the center dome manway prior to reducing the silo residue volume.

Table 5-2 lists the basic equipment required for the recommended scenario. Additional costs will be required for deployment of Houdini for discrete object and heel retrieval; however, if Houdini were deployed at grade, costs would be less than deployment from a support structure. A relative order of magnitude cost is provided for each piece of recommended equipment, along with an estimated lead time for procurement. The equipment identified for the recommended alternative is largely standard catalog or readily available items which will not require specialized design, modification, or manufacture.

The capital cost for the primary pieces of removal equipment required for bulk retrieval of the Silo 3 residues using the recommended scenario is estimated to be less than $210,000. The maximum lead time associated with this equipment should not exceed 20 weeks.

Development of the recommended equipment will proceed with the conceptual design in PO-161, which will include more detailed equipment descriptions and catalog cuts, where applicable.

Table 5-2 - Silo 3 Recommended Residue Retrieval Equipment

Equipment Description	Capital Cost	Lead Time (weeks)
Silo Backing Plate for Wall Cut (two required)	$20,000	20
Equipment Enclosure at Grade (two required)	$40,000 (total)	12
Mechanically Assisted Pneumatic Device (two required)	$65,000 (total)	16
Segmented Vacuum Tube	$10,000	12
Silo Cutting Equipment	$10,000	12
Vacuum Filter/Receiver	$25,000	12
1/2 hp Receiver Rotary Airlock	$3,000	8
10 hp Turbo Exhauster	$35,000	20

5.4 Recommended Testing and Activities

5.4.1 Solids Physical Properties

Accurate data regarding the residue solids' physical properties are critical in designing the pneumatic retrieval system as well as the pneumatic transport system to the FRVP. Additional particle size analysis is required, since previous particle size analysis data less than 22 microns was inaccurate.

5.4.2 Silo Wall Cut Demonstration

Silo 4 provides an excellent opportunity to demonstrate the proposed wall cuts which will be required on Silo 3 for retrieval operations. Silos 3 and 4 are of identical construction and age, and have weathered similarly. This demonstration would include installation of the silo backing plate (banding), cutting of the initial 8-inch-diameter opening, and the subsequent enlargement of the opening. The demonstration would be performed prior to the actual Silo 3 cuts by the same firm contracted to perform the Silo 3 modifications. The purpose of this demonstration is to increase operator familiarity with the actual conditions and equipment rather than demonstrate the adequacy of the selected technology. The cost for this activity is estimated to be in the range of $25,000 and is considered minor in relation to the level of confidence and familiarity it would provide for the actual cutting operations.

SECTION 6

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